

# **The National Near-Earth Object Preparedness Strategy and Action Plan: Progress to Date**

**Presented to the  
SSERVI Exploration Science Forum  
NASA Ames Research Center  
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## ASSESS

[CENTER FOR NEAR EARTH  
OBJECT STUDIES]



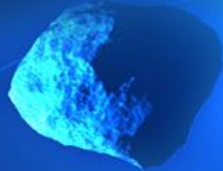
## SEARCH, DETECT & TRACK

[GROUND-BASED & SPACE-BASED  
OBSERVATIONS, IAWN]



## MITIGATE

[DART, FEMA EXERCISES]



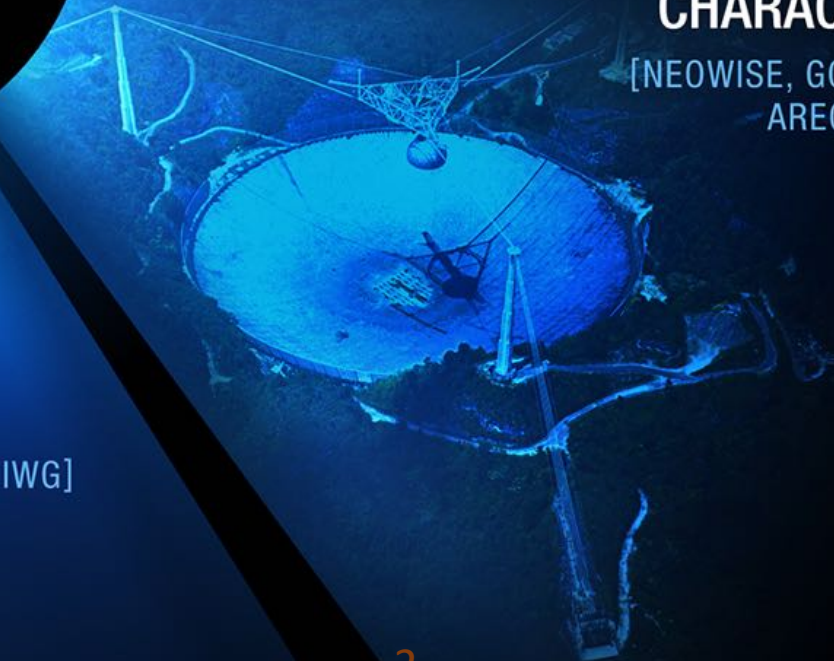
# PLANETARY DEFENSE

## PLAN & COORDINATE

[SMPAG, PIERWG, DAMIEN IWG]

## CHARACTERIZE

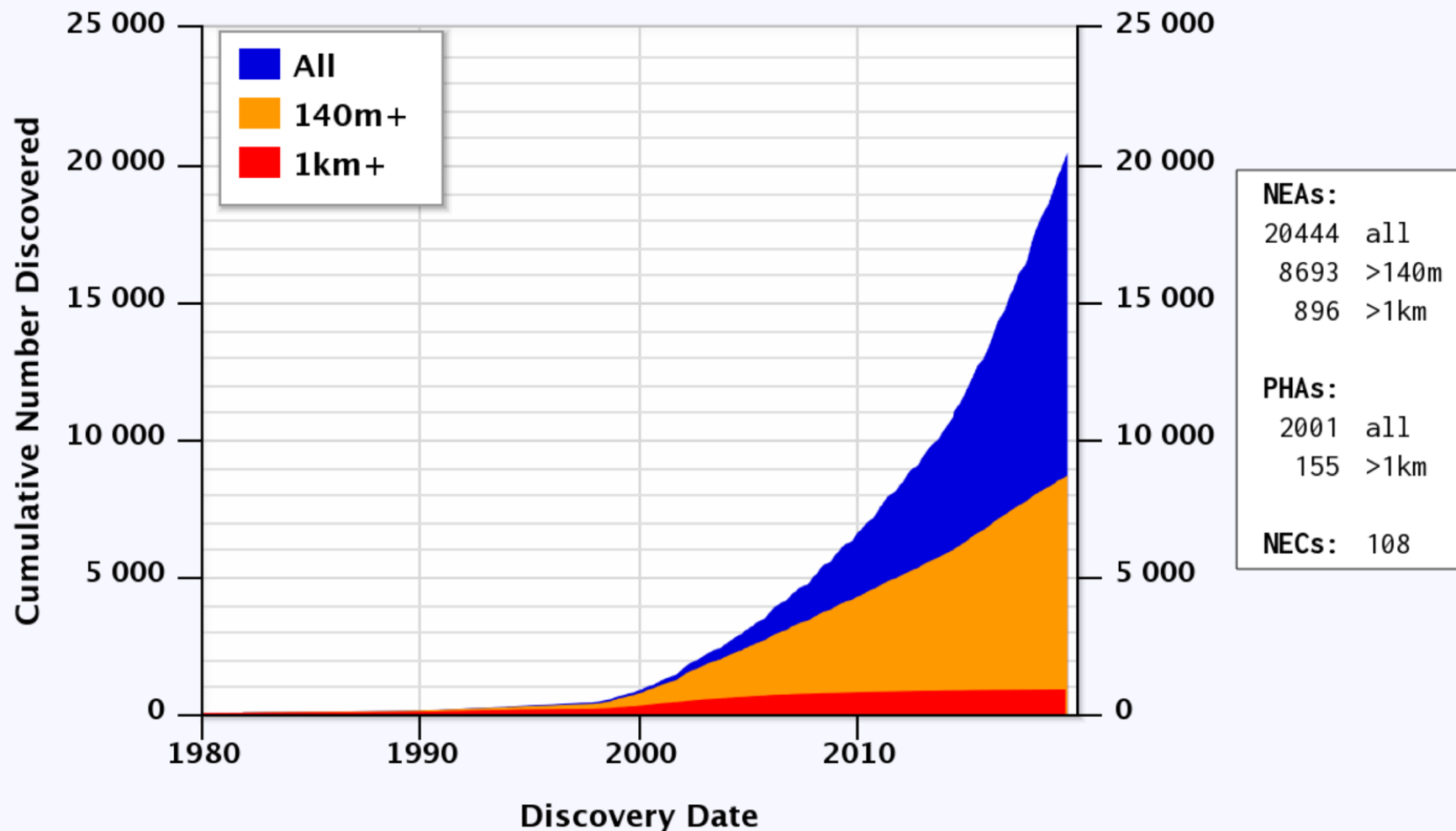
[NEOWISE, GOLDSTONE,  
ARECIBO, IRTF]



# NEAs 140 Meters and Larger

## Near-Earth Asteroids Discovered

Most recent discovery: 2019-Jul-15



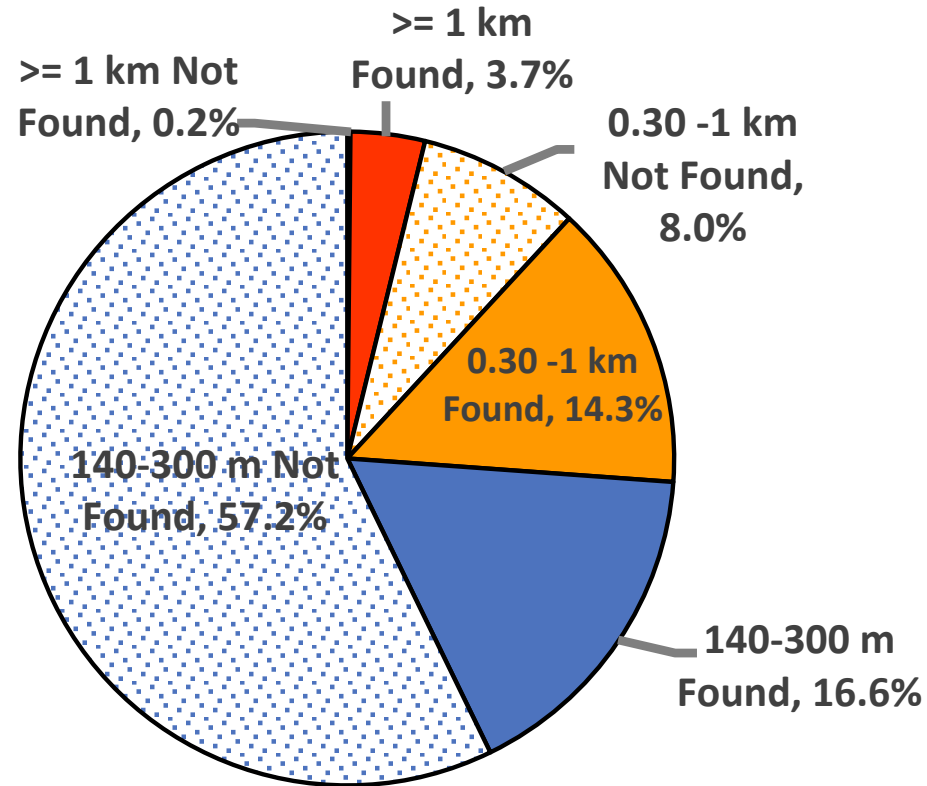
*\*Potentially Hazardous Asteroids (PHAs) come within 7.5 million km of Earth's orbit*



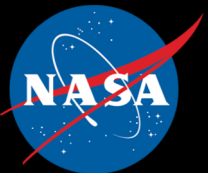
# Progress: 140 Meters and Larger

Total Population estimated to be ~25,000

NEO Survey Status Jan 2019



At current discovery rate, it will take more than 30 years to complete the survey.





# Why The *Action Plan* is Important

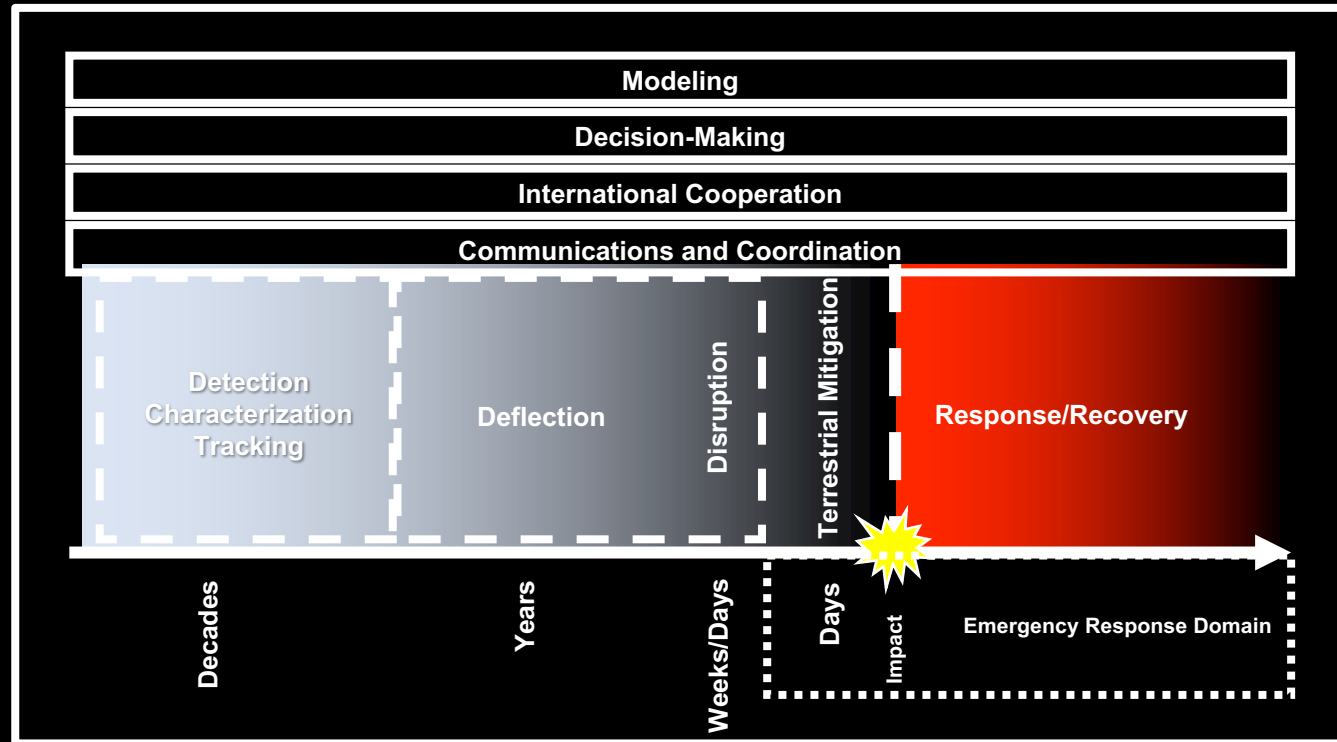
- Large and small asteroid impacts have occurred in the past, with effects that are comparable to, or more devastating than, those created by nuclear explosives.
- The *Action Plan* represents the first step for the U.S. to identify and develop possible responses to this hazard because:
  - NASA can't do it all
  - The solution may require an all-of-government approach in which significant capabilities should be brought to bear by other government agencies
  - The emergency would probably necessitate an international response
- Possible responses to the hazard may not be easily accomplished or may require long-lead development, even with a plan in place:
  - If the object is big enough and near enough, other government agencies would have to take the lead and would need to be prepared
  - There probably won't be enough time to start planning from a blank sheet of paper
- ...And because the Nation's 'engineered environment' is far more fragile, and humans much more numerous, than in the past.



# Planetary Defense Timeline\*

Multiple agencies and organizations have responsibilities to provide input to understanding the threat, and determining a response.

Unlike other natural disasters or space weather events, asteroid impacts can be predictable many years in advance, and, potentially are preventable. However, this capability requires advance coordination by multiple agencies and organizations.



\* Source: National NEO Preparedness Strategy and Action Plan, June 2018



# White House Guidance released on 20 June 2018

<https://www.whitehouse.gov/wp-content/uploads/2018/06/National-Near-Earth-Object-Preparedness-Strategy-and-Action-Plan-23-pages-1MB.pdf>



## NATIONAL NEAR-EARTH OBJECT PREPAREDNESS STRATEGY AND ACTION PLAN

*A Report by the*  
INTERAGENCY WORKING GROUP FOR DETECTING AND MITIGATING  
THE IMPACT OF EARTH-BOUND NEAR-EARTH OBJECTS  
  
*of the*  
NATIONAL SCIENCE & TECHNOLOGY COUNCIL

JUNE 2018



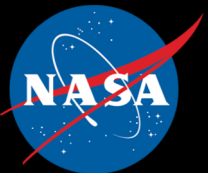
PLANETARY DEFENSE  
COORDINATION OFFICE

# National NEO Preparedness Strategy and Action Plan

## Goals in the New Action Plan

- Enhance NEO detection, characterization, and tracking capabilities
- Improve modeling, predictions, and information integration
- Develop technologies for NEO deflection and disruption
- Increase international cooperation on NEO preparation
- Establish NEO impact emergency procedures and action protocols

The Action Plan lists 32 actions assigned to different agencies to be completed on different timelines. Highlights follow...



# Goal 1: Enhance NEO Detection, Characterization, and Tracking Capabilities

**Objective:** Improve national capabilities for NEO detection, tracking, and characterization

**Actions:**

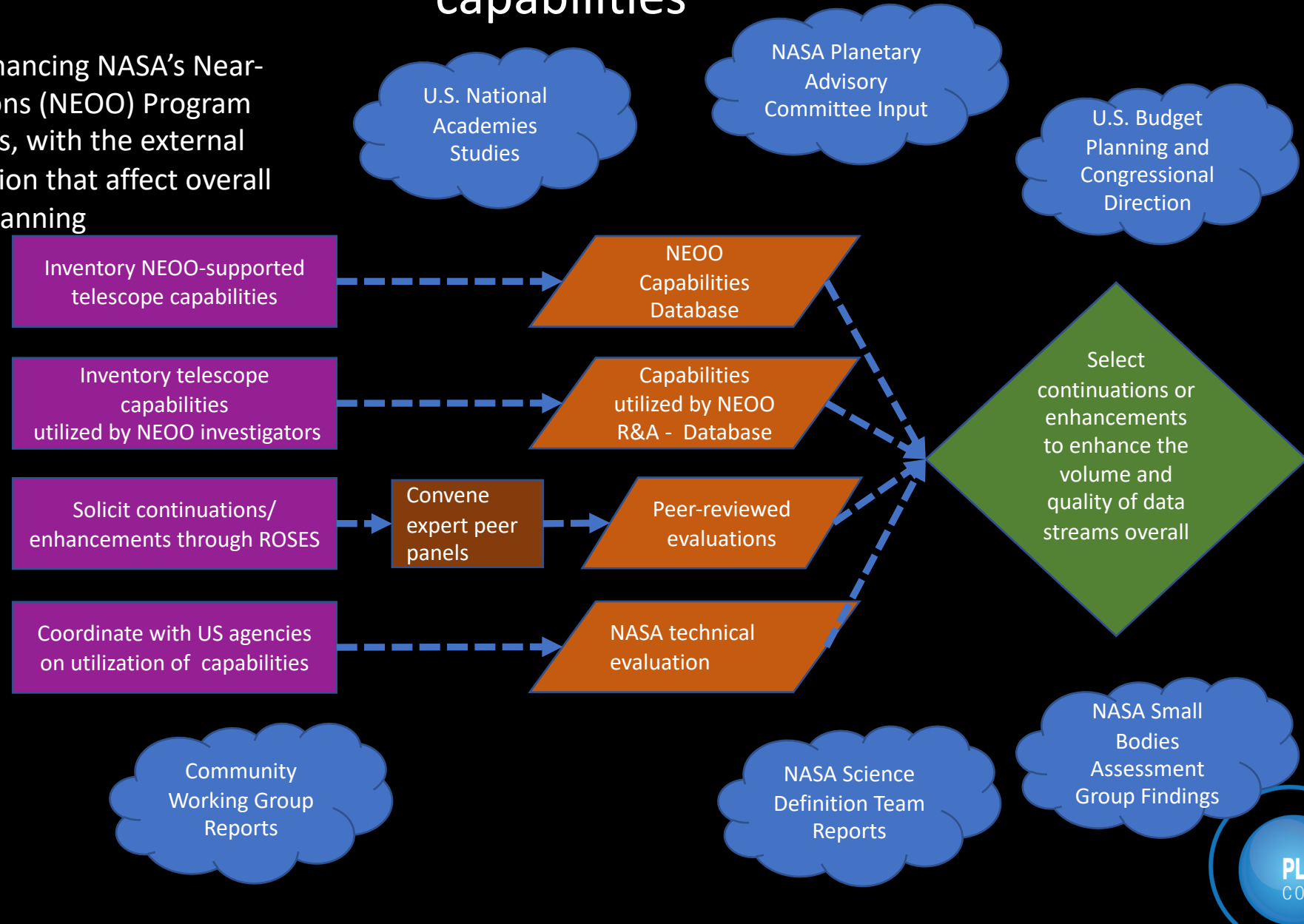
1. Identify opportunities in existing and planned telescope programs to improve detection and tracking by enhancing the volume and quality of the current data streams, including from optical, infrared, and radar facilities
  - *Activity: NASA PDCO is assessing planned and potential improvements*
2. Identify technology and data processing capabilities and opportunities in existing and new telescope programs to enhance characterization of NEO composition and dynamical and physical properties
  - *Activity: NASA PDCO is assessing planned and potential improvements*
3. Use the roadmaps developed in Actions 1.1 and 1.2 to inform investments in telescope programs and technology improvements to improve completeness and speed of NEO detection, tracking, and characterization
4. Establish and exercise a process for rapid characterization of a potentially hazardous NEO
  - *Activity: Successful 2018 re-capture, tracking and characterization of 2018 TC4 yielded excellent results and lessons learned*





# NASA's Near-Earth Object Observations (NEOO) Program projects and capabilities

Process for selecting/enhancing NASA's Near-Earth Object Observations (NEOO) Program projects and capabilities, with the external considerations and direction that affect overall strategic planning



# Goal 2: Improve Modeling, Predictions, and Information Integration

## Objectives:

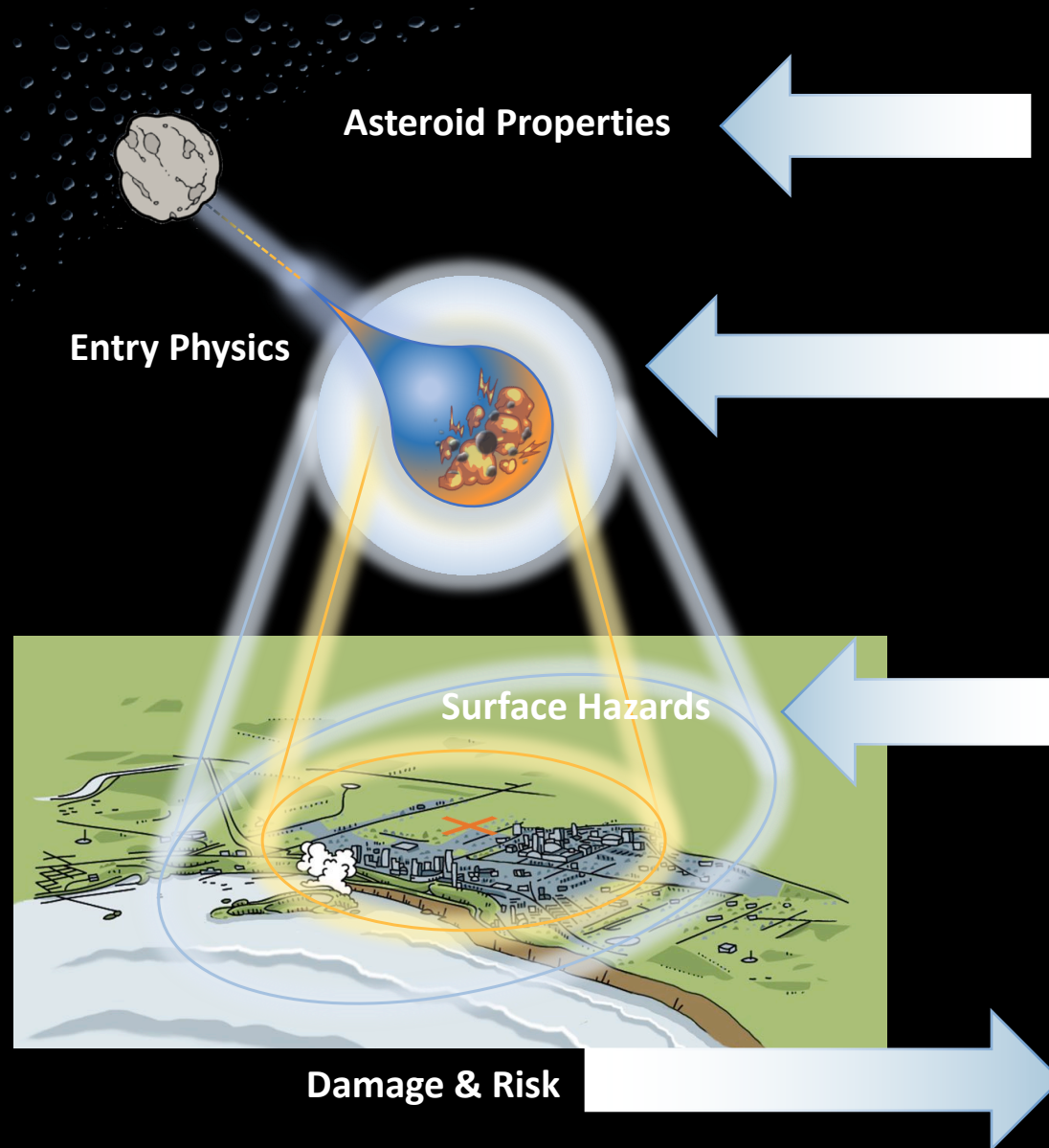
- Establish an interagency NEO impact modeling working group
- Establish an integrated suite of computational tools for modeling NEO impact risks and mitigation techniques
- Exercise, evaluate, and continually improve modeling and analysis capabilities

## Actions:

1. Establish an interagency working group for coordination and enabling dissemination of the results of NEO threat modeling and analysis
  - *Activity: Working Group established and is coordinating plans for technical interchange meetings, exercises, and white papers.*
  - *The remainder of the Actions below are being worked by the WG.*
  - *The WG currently plans an exercise in November 2019 that will map and test the information/decision flows that currently exist and could be called upon in an impact scenario.*
  - *Membership includes NASA PDCO, DOE Los Alamos and Sandia National Labs, NOAA.*
2. Ascertain what information each participating organization requires on what timeframe, identify gaps, and develop recommendations for modeling improvements
3. Develop and validate a suite of computer simulation tools for assessing the outcome of deflection or disruption techniques applied to a NEO
4. Establish a suite of computer simulation tools for assessing the local, regional, and global risks associated with an impact scenario
5. Assess the sensitivities of these models to uncertainties in NEO dynamical and physical properties
6. Continually assess the adequacy and validity of modeling and analysis through annual exercises, test problems, and comparison to experiments, and peer review activities



# Asteroid Threat Assessment



## Characterization

- Measurements
- Inference
- Data aggregation
- Property database website

## Entry Simulations & Testing

- Coupled aerothermodynamics
- Ablation & radiation modeling
- Arc jet testing

## Hazard Simulations

- 3D blast simulations
- Impact crater simulations
- Tsunami simulations
- Thermal radiation models
- Global effects

## Probabilistic Risk Assessment

- Analytic physics-based entry and damage models
- Probabilistic Monte Carlo simulation using uncertainty distributions

# Goal 3: Develop Technologies for NEO Deflection and Disruption

## Objectives:

- Develop technologies and designs for rapid-response NEO reconnaissance missions
- Develop technologies and designs for NEO deflection and disruption missions

## Actions:

1. Assess technologies and concepts for rapid response NEO reconnaissance missions  
*Activity: An interagency working group is conducting this assessment and will start planning for the remaining Actions for this Goal.*
  - Reconnaissance mission architecture trades are being studied that will be used to inform potential mission concepts
  - Parametric studies of potential instruments suites will be conducted in FY2020
  - Membership includes NASA, DOE/NNSA and the National Labs
2. Evaluate the capabilities of current and projected domestic and international launch vehicle infrastructure to support planetary defense missions
3. Create plans for the development, testing, and implementation of NEO reconnaissance mission systems
4. Identify, assess the readiness of, estimate the costs of, and propose development paths for technologies required by NEO impact prevention concepts
5. Perform a risk analysis on planetary defense mission success under varying assumptions and circumstances
6. Develop preliminary mission designs for NEO deflection mission campaigns
7. Conduct a series of flight demonstrations to validate NEO deflection and disruption system concepts



# Double Asteroid Redirection Test (DART)

## Technology Demonstration of Kinetic Impactor Technique

### DART Spacecraft

540 kg Arrival Mass

20m<sup>2</sup> ROSA

NEXT Thruster, DRACO Imager

6.0 km/s Closing Speed

### Cubesat

6U Argomoon Design

WFOV and NFOV Imagers

Agenzia Spaziale Italiana

### Earth-based Observations

~7M mile Range at Impact

### Didymos-A

1996 GT

S-Type Apollo

780 meter size

### Didymos-B

~160 meter size

Kinetic impact will change  
Didymos moon's velocity in orbit,  
and thereby its orbital period,  
which can be detected from Earth  
observatories



# Goal 4: Increase International Cooperation on NEO Preparedness

## Objectives:

- Build international awareness of potential NEO impacts as a global challenge
- Increase international engagement and cooperation on observation infrastructure, numerical modeling, and scientific research
- Foster consultation and coordination of NEO impact planning, mitigation and response

## Actions:

1. Inform foreign governments of the need for a comprehensive and coordinated approach to preparing for a NEO event
2. Continue to demonstrate U.S. leadership in technical international NEO organizations, and increase awareness among all countries, in particular space agency officials, of the need to address NEO issues in major international bodies
3. Improve international collaboration on observation infrastructure and data sharing, as well as numerical modeling, and scientific research
4. Lead development of a plan for improving NEO monitoring through enhanced coordination (and potential expansion) of U.S. and key country ground-based telescopes
5. Encourage countries around the world to initiate and continue programs to develop space-and ground-based telescopes to detect, track, and characterize NEOs and coordinate via the IAWN
  - *Activity: The International Astronomical Union Planetary Defense Conference 2019 (as well as all PD conferences since 2013) includes an international exercise. Exercises have been conducted by ESA and other agencies are considering more.*
6. Strengthen the IAWN and SMPAG as the primary international technical bodies for addressing NEO planning and mitigation
7. Encourage participation in tabletop and physical exercises with global partners regarding preparedness, prevention, response, and recovery efforts

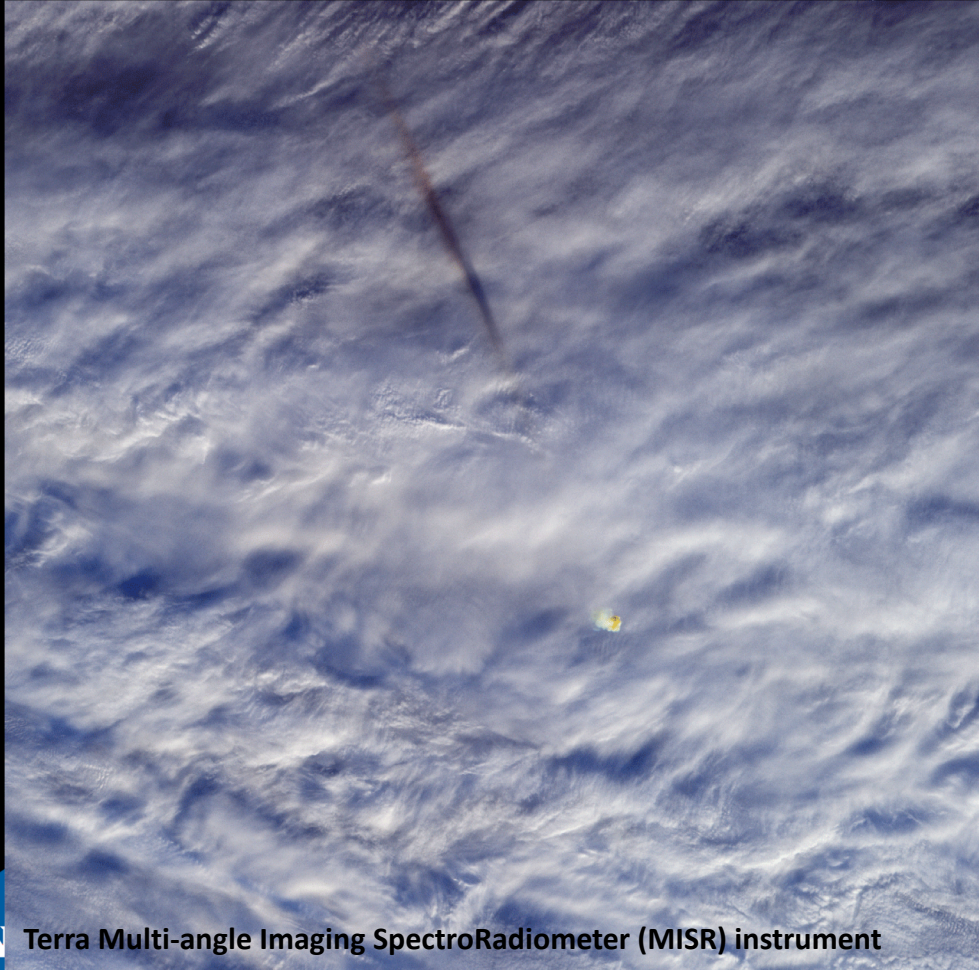


# Bering Sea Impact, 18 Dec 2018

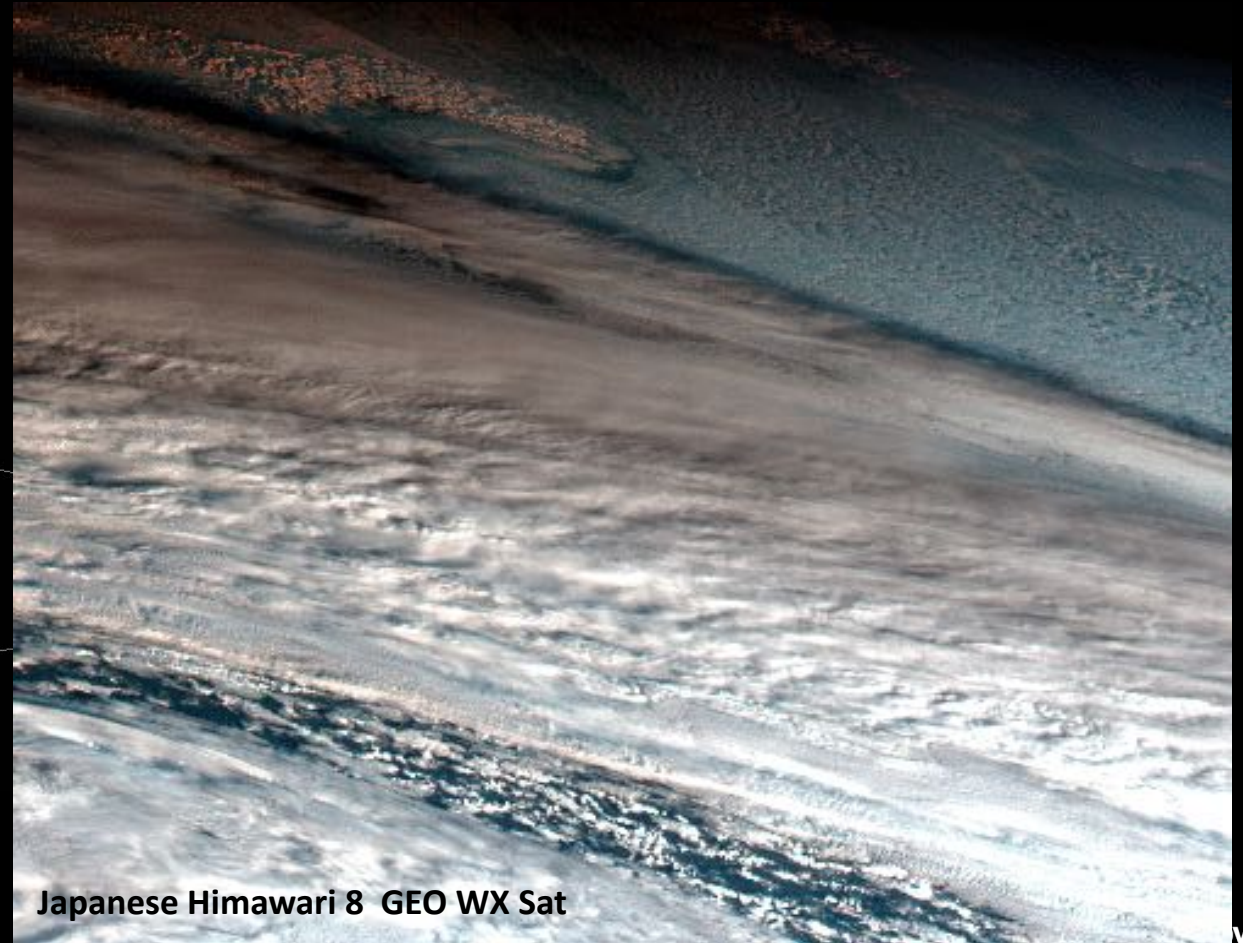
## 173 (?) kton event

### Final Approach Trajectory of the Bering Sea Impactor

- 4 hrs



Terra Multi-angle Imaging SpectroRadiometer (MISR) instrument



Japanese Himawari 8 GEO WX Sat

# Goal 5: Establish NEO Impact Emergency Procedures and Action Protocols

## Objectives:

- Strengthen protocols for conducting a threat-assessment, upon detection of a potential NEO impact, to inform subsequent communication and decision making
- Establish protocols for recommending space-based reconnaissance and mitigation missions
- Establish procedures and protocols for recommending and executing NEO impact emergency preparedness, response, and recovery

## Actions:

1. Develop a set of real-world scenarios based on credible impact threats with observable parameters to inform planning and procedure development
  - *Activity: NASA/FEMA have agreed that the previous NASA-FEMA Table Top Exercises are models for the test scenarios*
2. Establish a procedure and timeline for conducting a threat assessment upon detecting a potential NEO impact, and for updating the threat assessment based on improved data
  - *Activity: Interagency Working Group has been stood up to review and make recommendations*
3. Revisit and validate the current notification protocol chain-of-command based on the response to Congress in an October 2010 OSTP memo
4. Develop protocols for notifying the White House and Congress (including briefing appropriate subcommittees), State and Local Governments, the public, foreign governments, and international organizations, regarding NEO threats
  - *Activity: Incorporate NEO impacts into All-Hazards Response and Recovery Plans*
5. Develop education material for different audiences providing basic education, information, uncertainties, and emergency response
6. Establish a procedure and timeline for conducting a risk/benefit analysis for space-based mitigation mission options following a NEO Threat Assessment
7. Develop benchmarks for determining when to recommend NEO reconnaissance, deflection, or disruption missions
8. Incorporate NEO impacts into All-Hazards Response and Recovery Plans





# National Response Framework

- The NRF is a guide to how the Nation responds to all types of disasters
- The NRF outlines responsibilities of Departments/Agencies (D/As) for 14 Emergency Support Functions (ESF)
  - An ESF is a mechanism to bundle like resources from across the Federal Government
  - D/As supporting ESFs may be selectively activated to support response activities
- The NRF is always in effect and elements can be implemented at any time

Emergency Support Functions (ESF)	
# 1	Transportation
# 2	Communications
# 3	Public Works & Engineering
# 4	Firefighting
# 5	Information & Planning
# 6	Mass Care, Emergency Assistance, Temporary Housing, Human Services
# 7	Logistics
# 8	Public Health & Medical
# 9	Search & Rescue
# 10	Oil & HazMat Response
# 11	Agriculture & Natural Resources
# 12	Energy
# 13	Public Safety & Security
# 15	External Affairs



# CONCLUSION

- Work has been initiated across all the Goals in the Action Plan
- Significant efforts will be undertaken in the next few years
- Our next milestone is a report to OSTP in late September 2019



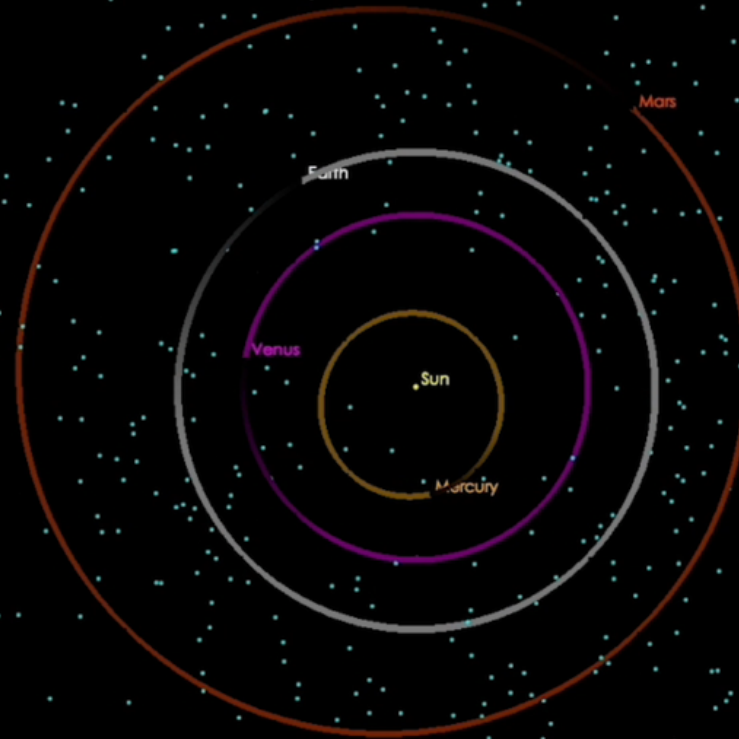




*Questions?*

[www.nasa.gov/planetarydefense](http://www.nasa.gov/planetarydefense)





**Known Near-Earth Asteroids Jan. 1, 1999**

# BACKUP



# Abstract

In June 2018, the White House published guidance to federal agencies with a goal to improve overall government preparedness in the event a probable impacting asteroid is detected. An impact by an asteroid or comet could pose significant and complex risks both to human life and critical infrastructure, and potentially cause global environmental and economic harm. The *Action Plan* provides a roadmap for a federally coordinated approach to improving overall U.S. preparedness to effectively respond. Completing these actions will improve detection, research, mission planning, emergency preparedness and response, and domestic and international engagement.

This presentation will summarize the *National Near-Earth Object Preparedness Strategy and Action Plan* and show progress made to date in implementing the actions in Plan.



# Planetary Defense Coordination Office

The Planetary Defense Coordination Office (PDCO) was established in January 2016 at NASA HQ to manage planetary defense related activities across NASA, and coordinate with both U.S. interagency and international efforts to study and plan response to the asteroid impact hazard.

## Mission Statement

Lead national and international efforts to:

- Detect any potential for significant impact of planet Earth by natural objects
- Appraise the range of potential effects by any possible impact
- Develop strategies to mitigate impact effects on human welfare





# Common Terms

- **“Near Earth Objects (NEOs)”- any small body (comet or asteroid) passing within 1.3 astronomical unit (au) of the Sun**
  - 1 au is the distance from Earth to Sun = ~ 150 million kilometers (km)
  - NEOs are predicted to pass within ~ 48 million km of Earth’s orbit, e.g. any small body passing between orbits of Venus to Mars
- NEOs may be:
  - Near Earth Asteroids (NEAs): 19,794 discovered as of 3/28/2019
  - Near Earth Comets (NECs) – also called Earth Approaching Comets (EACs) are < 1% of the total NEO population: 107 currently known
- **“Potentially Hazardous Objects (PHOs)” – a small body that has potential risk of impacting the Earth at some point in the future – are a subset of the NEO population**
  - NEOs passing within 0.05 au of Earth’s orbit
  - Pass within ~ 8 million km = 20 times the distance to the Moon
  - Are estimated to be >140m in size
  - This appears to be about 20% of all NEOs larger than 140 meters discovered to date
  - PHAs = Potentially Hazardous Asteroids
- Asteroids are small rocky bodies; comets are small icy and rocky bodies that sometimes form a visible atmosphere (coma) and tail when approaching the Sun inside the orbit of Jupiter



In space:

< 1 meter = Meteoroid

> 1 meter = Asteroid



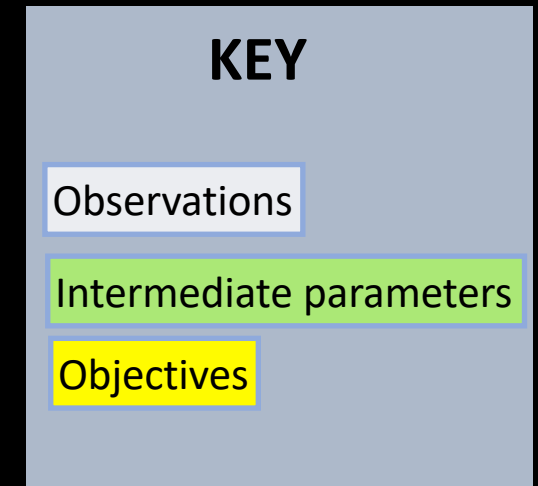
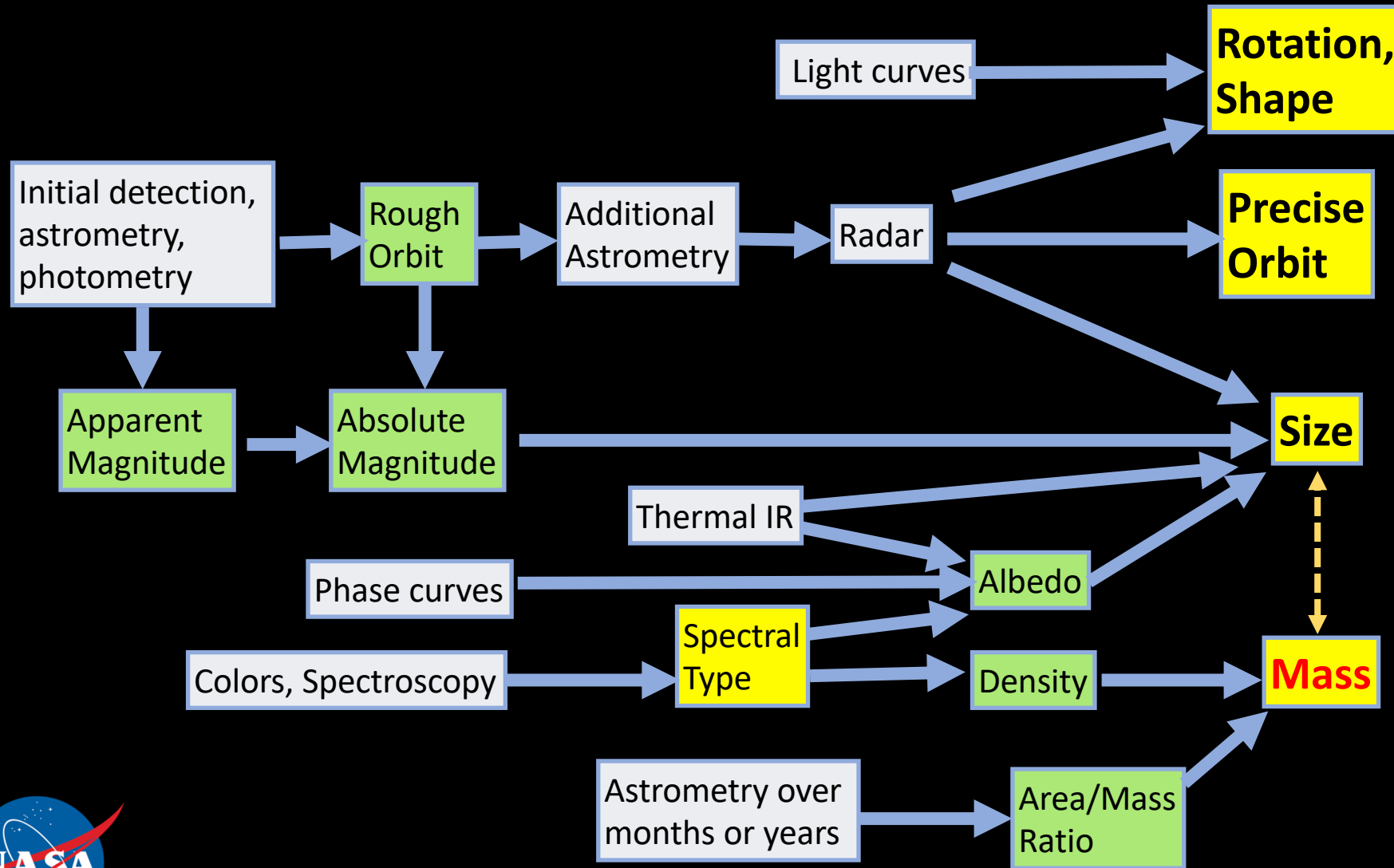
Meteor: in atmosphere



Meteorite: on ground



# NEO Characterization Process



# Asteroid Impact Effects vs. Object Size

Diameter of Impacting Asteroid	Type of Event	Approximate Impact Energy (MT)	Average Time Between Impacts (Years)
5 m (16 ft)	Bolide	0.01	1
10 m (33 ft)	Superbolide	0.1	10
25 m (80 ft)	Major Airburst	1	100
50 m (160 ft)	Local Scale Devastation	10	1000
140 m (460 ft)	Regional Scale Devastation	300	20,000
300 m (1000 ft)	Continent Scale Devastation	2,000	70,000
600 m (2000 ft)	Below Global Catastrophe Threshold	20,000	200,000
1 km (3300 ft)	Possible Global Catastrophe	100,000	700,000
5 km (3 mi)	Above Global Catastrophe Threshold	10,000,000	30 million
10 km (6 mi)	Mass Extinction	100,000,000	100 million

